"ON THE COMPOSITION OF SIRIUS" REVISITED

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In a recent criticism of our abundance analysis of Sirius and Vega,[1] Warner[2] has pointed to the "devastating effect" of setting the microturbulent velocity to zero in the computations. He denies our conclusions that Sirius is metal-rich and that its relative metal abundances resemble those of a metallic-line star, and he calls for a complete reanalysis of the data with proper allowance for microturbulence.

Although our original choice of zero microturbulence (after a discussion of the difficulties encountered in the assignment to it of a more meaningful value) left something to be desired, we can now report that the requested reanalysis vindicates our original conclusions.

In order to obtain abundances of higher accuracy in Sirius and Vega, we have repeated our model atmosphere analysis using various microturbulent velocities. In keeping with the new T_{eff} scale suggested by Hanbury Brown et al.,[3] we have used a (9500°, 3.7; 1) model for Vega and a (10,000°, 4.2; 10) model for Sirius.* These temperatures are 500 K° higher than those used in our original analysis. In any event, the lower Balmer discontinuity of Sirius as well as the measurements of Hanbury Brown et al. and Hayes' new calibration of the Vega continuum[4] seems to require Sirius to be at least a few hundred degrees hotter than Vega.

*The scheme for designating models is (T_{eff}, log g; metal abundance/solar metal abundance).

After deriving the abundances for the two stars with various assumed values for the microturbulence, we chose the "best" value for v_t of 3.0 ± 0.5 km/s for both Sirius and Vega so that the abundances for the individual Fe and Ti II lines showed the least dependence on equivalent width. The results for all the Fe lines are shown in Fig. I. We note that the discrepancy between abundances derived from Fe I and Fe II would have been minimized if the lower temperatures had been retained or if a higher gravity had been chosen; Warner's f values for Fe I and Fe II, which we adopted, give consistent results for the Sun. The final adopted abundances will depend on how the weak lines are weighted in the average, but the figure clearly reveals the higher iron abundance of Sirius.

Use of the 3-km/s microturbulence does indeed diminish the derived abundance of silicon, although not enough to alter our conclusion that silicon is distinctly overabundant in Sirius relative to Vega. We note that silicon is the only element appreciably affected and that the abundance deduced from the 10 Si II lines <u>still</u> shows a marked dependence on equivalent width even with v_t = 3 km/s. The equivalent-width/abundance dependence for the Si II lines disappears if a microturbulence of 6 km/s is adopted for just this species. Since these lines are formed preferentially deeper within the narrow zone of convective instability in the atmosphere, our results may suggest a depth dependence of v_t. The overabundance of Si II is somewhat less with v_t = 6 km/s in the Sirius model, but still a factor of 4 greater than in a Vega model with v_t = 3 km/s. The abundance difference is, of course, even greater if a larger microturbulence is assumed for this species in Vega. In any event, Warner certainly chose a nontypical example in order to demonstrate the devastating effects of ignoring microturbulence.

If we repeat the Sirius analysis with a (10,000°, 4.2; 1) model, that is, with a solar metal composition in the opacities, the deduced abundances differ by 25 per cent or less, in contradiction to Warner's comment that our choice of a metal-rich model adversely affects our results.

In Table I we present logarithmic abundances (with respect to hydrogen at 12.0) for Vega and Sirius using $v_t = 3$ km/s, the models indicated above, and the equivalent widths observed by Hunger[5] for Vega and by Köhl[6] for Sirius. For comparison, we have included the GMA solar abundances[7] the results of our previous analysis for Sirius, and the results for $v_t = 0$ for Sirius based on a (10,000°, 4; 1) model. Our results for Sirius are in close agreement with those of Köhl;[8] the fact that Köhl's analysis used $v_t = 2$ km/s was apparently forgotten by Warner.

Our analysis yields the following conclusions:

(i) Changes of T_{eff} up to 500 K° have little effect on most of the metal/Fe ratios, although the absolute abundances are, of course, changed;

(ii) Sr, Ba, and Ni are overabundant with respect to Fe in Sirius relative to Vega;

(iii) Sc, Ca, C, N, and O are underabundant with respect to Fe in Sirius relative to Vega;

(iv) The abundance of Fe compared to that of H is enhanced by a factor of 8 in Sirius relative to Vega;

(v) The abundance of Si compared to that of H is enhanced by a factor of at least 4 in Sirius relative to Vega.

Hence, Sirius clearly has many of the abundance anomalies of a classical Am star.

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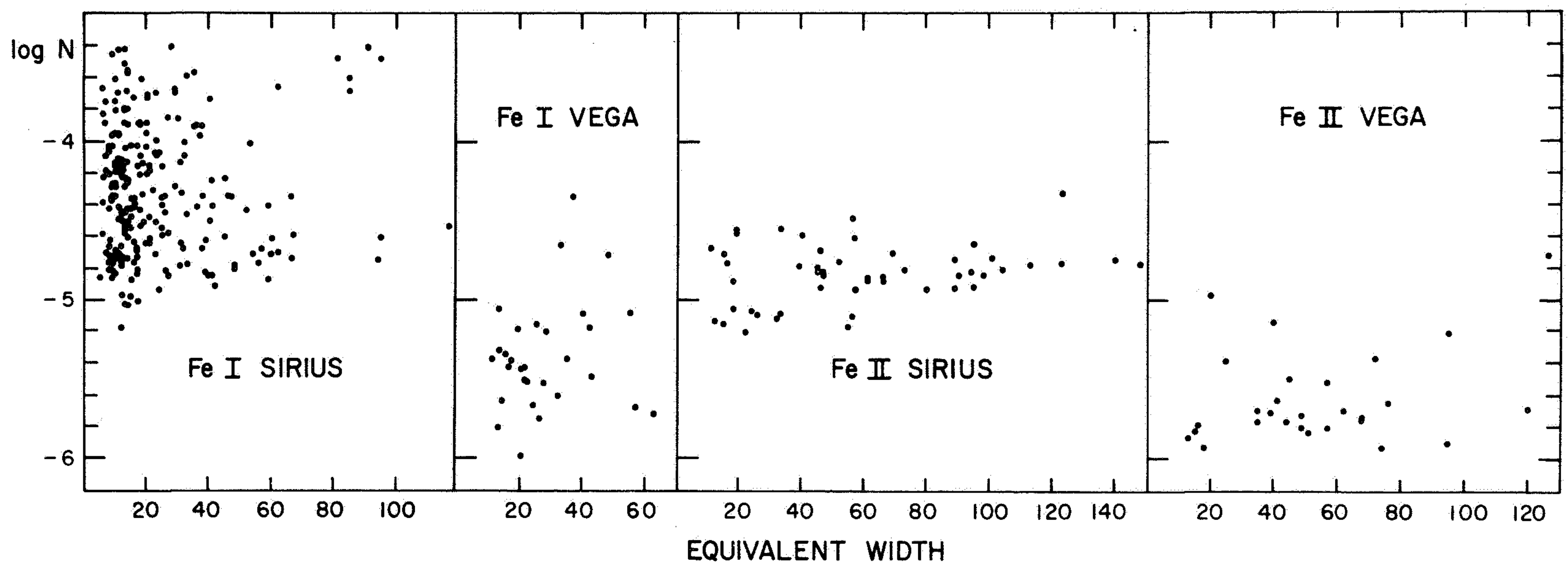

Fig. I

The higher abundance of Fe I and Fe II in Sirius is independent of the equivalent widths of the lines used, as shown by the plot of the logarithm of the abundance versus equivalent width.